Naval Submarine Medical Research Laboratory

A Comparison of the Prevalence of Metabolic Syndrome among Fast-Attack Submariners with U.S. Civilian Males

by

Hartwell J, Durocher N, Gertner J, Vanderweele J, Marvin K, Horn W

Approved and Released by:
D.G. SOUTHERLAND, CAPT, MC, USN
Commanding Officer
NAVSUBMEDRSCHLAB

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Hartwell J, Durocher N, Gertner J, Vanderweele J, Marvin K, Horn W

Naval Submarine Medical Research Laboratory

Approved and Released by:

CAPT D.G. Southerland, MC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory
Submarine Base New London Box 900
Groton, CT 06349-5900

ADMINISTRATIVE INFORMATION

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ABSTRACT

Submariners have historically served in an environment characterized by prolonged physical inactivity and excessive caloric intake. These two conditions are established risk factors for metabolic syndrome. In recent years, metabolic syndrome has garnered attention due to its association with increased risk of cardiovascular disease and diabetes mellitus. There is a concern among Undersea Medicine Officers that the prevalence of metabolic syndrome is on the rise within the submarine community, leading to a potential health care crisis for these servicemen years after they have completed their tours of duty. This paper presents and compares several currently accepted criteria for metabolic syndrome, then applies them to a sample population of local submariners in order to generate prevalence estimates for the nearly 3000 sailors serving onboard fast-attack submarines stationed at Groton, CT. These estimates are further analyzed on the basis of age, body-mass index, and rank to compare prevalence rates with the civilian U.S. population and identify the subset of the study population at greatest risk for developing metabolic syndrome. Finally, recommendations are made for future screening of submariners to include fasting blood glucose as a standard test.

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INTRODUCTION

Among the more pressing health concerns for sailors is the potential decline of physical fitness over time, particularly after joining the fast-attack submarine fleet. With the limited space available on these boats, there is seldom room for more than a few pieces of exercise equipment among a crew of approximately 140 people. Therefore, it is difficult for submariners to engage in regular physical activity onboard, simply due to inadequate facilities. This shortage of equipment, combined with a demanding operational tempo and the chronic circadian disruption associated with an eighteen-hour work cycle leaves little motivation or energy remaining to focus on physical fitness while aboard a submarine.

The diet of the submariner while underway does little to mitigate the effects of this lack of physical activity. Room for perishable items within the ship's stores is scarce. While commands at sea attempt to make healthy choices available, nothing prevents individuals from ignoring portion control or making poor diet choices. With full meals served every six hours, caloric intake can greatly exceed expenditure among submariners. This combination of sedentary lifestyle and excessive caloric intake poses an increased risk for metabolic syndrome, a clustering of abnormalities correlated with increased risk of developing serious medical conditions including cardiovascular disease (CVD), diabetes mellitus (DM), stroke, and nonalcoholic fatty liver disease (NAFLD).[1-6]

Metabolic Syndrome

Metabolic syndrome is an agreed-upon term for the collection of clinical abnormalities that have been described for over 20 years in the medical literature. Other less common names include Obesity Dyslipidemia Syndrome, Insulin Resistance Syndrome, Syndrome "X", The Deadly Quartet, and Hypertriglyceridemic Waist.[4,8] Research has shown that the constellation of abnormalities of metabolic syndrome is more dangerous than the individual risk factors in isolation.[7] Specifically, having metabolic syndrome doubles a person's odds of cardiovascular mortality and triples the likelihood of suffering a heart attack or stroke.[8] Further, metabolic syndrome quintuples an individual's odds of developing DM, complications of which comprise the fifth leading cause of death in developed nations.[5]

Metabolic syndrome currently has several conventionally accepted definitions with a high degree of overlap. Most definitions require at least three of the following five abnormalities in order to establish the diagnosis: hypertension (HTN), elevated serum triglycerides (TG), elevated fasting blood glucose (FBG), deficient High-Density Lipoprotein cholesterol (HDL), and central obesity.[1-3,5,6] Definitions of metabolic syndrome differ largely in their cutoff limits and criteria for measuring obesity.

In 1998, the World Health Organization (WHO) proposed a definition emphasizing insulin resistance as the underlying risk factor for metabolic syndrome.[4] Diagnosis was made in patients with insulin resistance in addition to at least two of the following: HTN, elevated TG, low HDL, central obesity, or microalbuminuria. Evidence for insulin resistance was obtained either directly with an insulin clamp or indirectly through testing

for impaired glucose tolerance, impaired fasting glucose, type 2 diabetes mellitus or impaired glucose disposal under hyperinsulinemic or euglycemic conditions.[7] The WHO definition is given no further consideration in this paper because urine microalbumin concentrations are not routinely collected from submariners.

In 1999 the European Group for the Study of Insulin Resistance (EGIR) proposed a definition of Insulin Resistance Syndrome similar to the WHO criteria for metabolic syndrome.[9] Like the WHO, the EGIR asserted that insulin resistance was a necessary prerequisite for metabolic syndrome, and that a diagnosis required plasma insulin levels in the upper quartile along with two of the other aforementioned clinical abnormalities. The EGIR definition differed from the WHO definition by including treatment for hypertension or dyslipidemia and excluding type 2 DM as clinical evidence of metabolic syndrome. The EGIR definition is given no further consideration in this paper because serum insulin concentrations are also not routinely collected from submariners.

In 2001 the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III or "ATP-III") published a definition of metabolic syndrome emphasizing central or visceral obesity rather than insulin resistance as the major underlying risk factor.[4] Unlike the WHO definition, the ATP-III definition lists no prerequisite conditions. Rather, individuals possessing or undergoing treatment for any three of the five aforementioned factors meet ATP-III criteria for metabolic syndrome.[10] The ATP III definition also differs significantly from the WHO definition by not requiring an insulin clamp, but instead measuring fasting blood glucose. Although the original guidelines set the cutoff for FBG at 110 mg/dl, the ATP-III Metabolic syndrome criterion was lowered to 100 mg/dl in 2004 to match the American Diabetes Association recommendations.[11] Consequently, the ATP III definition is currently the most commonly employed criteria in medical research because of its ease of use in epidemiological studies.[7]

In 2003 the American College of Endocrinology (ACE), working in conjunction with the American Association of Clinical Endocrinologists (AACE), proposed a unique definition for Insulin Resistance Syndrome that shifted focus away from abdominal obesity.[3,4] Unlike previous definitions, diagnosis involved presence of one or more specified increased risk factors for insulin resistance. The risk factors cited by ACE in their position statement included (1) a personal history of CVD, essential hypertension, NAFLD or acanthosis nigricans, (2) a family history of type 2 DM, hypertension or CVD, (3) history of glucose intolerance (4) non-Caucasian ethnicity, (5) sedentary lifestyle, (6) obesity, indicated by BMI > 25.0 kg/m^2 or waist circumference >40 inches, (7) age >40 years. Of these risk factors, degree of obesity and sedentary lifestyle were described in the position statement as "the most powerful modulators of insulin action." For that reason, it is noteworthy that the exact meaning of "sedentary lifestyle" is left to the clinical judgment of the diagnosing physician. ACE criteria for metabolic syndrome include at least one of the above prerequisites in conjunction with only two or more of elevated TG, low HDL, HTN, or impaired glucose metabolism, as evidenced by either elevated fasting glucose or 75 gram oral glucose tolerance test (OGTT). Despite the

broader criteria employed by this definition, the ACE proposed definition is not used typically in prevalence studies.

Most recently, the International Diabetes Federation (IDF) proposed an alternate definition of metabolic syndrome in 2004 to facilitate early detection and intervention. It was designed to provide a simplified diagnostic tool based upon easily obtainable measurements and laboratory values.[11] Unlike the ATP-III criteria, central obesity is an essential prerequisite for metabolic syndrome, rather than just a sufficient condition.[1, 4] Thus, if central obesity is present, either presence of or treatment for any two of the four aforementioned risk factors will establish diagnosis of metabolic syndrome according to IDF criteria.[11] Internationally, the IDF definition specifies different cutoffs for waist circumference on the basis of race in an attempt to make the definition more comprehensive. However for Americans the IDF recommends a single cutoff value, regardless of race.[5] As a consequence of its utility, the IDF definition appears with increasing frequency in current literature.

While there is a high degree of precision and accuracy in measuring blood pressure and serologic markers, obtaining central obesity data is often problematic when performing prevalence studies. Although a standardized method exists to measure abdominal circumference using a spring-handled tape measure, this technique is subject to user error and is not widely employed. Consequently, many studies have substituted a BMI $\geq$ 30 for central obesity when estimating prevalence using ATP-III criteria.[12] However, a study by Lean et al demonstrated a strong correlation between BMI and waist circumference, concluding with 96% sensitivity and 98% specificity that a BMI $\geq$ 25 and 30 corresponded to waist circumferences $\geq$ 94 cm and 102 cm, respectively.[13] Similar conclusions have been drawn regarding data sampled from the U.S. population.[3]

Table 1 compares the definition limits used in this study, which further illustrates the major differences between the criteria. Note that with the exceptions of differences in BMI cutoff and central obesity as a necessary condition for metabolic syndrome according to the IDF, the ATP-III and IDF definitions are in agreement.

Table 1. A comparison of widely used definitions of metabolic syndrome.

	ATP-III	IDF
BMI (kg/m^2)	$\geq$30	$\geq$25
FBG (mg/dL)	$\geq$100	$\geq$100
HDL (mg/dL)	<40	<40
TG (mg/dL)	$\geq$150	$\geq$150
Systolic BP (mmHg)	$\geq$130	$\geq$130
Diastolic BP (mmHg)	$\geq$85	$\geq$85

Methods

This project was approved and conducted under the guidance of the Naval Submarine Medical Research Laboratory Institutional Review Board to ensure protection and privacy of all information obtained during the course of this study. Data was collected

between the months of July 2007 and May 2008. All individuals involved in the analysis were directly assigned to the submarines involved. Only sailors assigned to fast-attack submarines stationed in Groton, CT as part of Submarine Group Two were assessed.

Data Collection

Most of the necessary data was obtained from individual sailor's Periodic Health Assessment (PHA). The PHA is a tool implemented to replace routine 5-year physicals to assess the medical readiness of individual service members.[14] In order to increase screening effectiveness and decrease burden on providers, every sailor in the U.S. Navy is required to undergo an annual PHA. Data obtained in the PHA includes blood pressure, fasting lipid panel, height, weight, and BMI calculation. Fasting blood glucose (FBG) is not required as part of the PHA. However, several laboratory facilities throughout the Navy include FBG as part of the fasting lipid panel. The most notable of these facilities is located at the Naval Hospital, Recruit Training Center at Great Lakes, which supports recruit training for the entire Navy. Shipboard PHAs are typically performed at the waterfront commands, with hard copies of any information obtained kept in each member's personal medical record onboard the submarine.

Despite the requirement for an annual PHA, numerous sailors did not have this screening tool documented in their medical records. Many of these sailors had not been in the Navy long enough to warrant the assessment, while others were simply lost to follow-up when transferring between commands. In any case, much of the necessary medical data to screen the sailors in question was subsequently obtained from their periodic submarine duty physical examinations.

Although the PHA eliminated the need for a periodic general duty physical examination, submariners undergo a thorough physical every 5 years to ensure their fitness for submarine duty. Blood pressure, height and weight data are required as part of the physical. Thus, this information is frequently available regardless of the PHA status. However, the submarine duty physical does not include FBG or lipid data unless the sailors are also Navy divers, or unless deemed necessary by a physician.[15] Consequently, this data is sometimes absent. Furthermore, the height and weight recorded in these physicals is often self-reported by the patient and is therefore unverified.

In order to determine the BMI of each member, Command Fitness Leaders from the submarines provided the latest Physical Fitness Assessment (PFA) data. The PFA is a test of strength and endurance that is required every 6 months for all active duty sailors. As part of the PFA, height and weight are objectively measured and recorded in an electronic database. Thus, this data was easily obtained and applied to the data set.

Anthropometric and serologic data from age-matched civilian controls were obtained from the recent National Health and Nutrition Examination Survey (NHANES) conducted from 2005-2006.[16] NHANES is a population-based survey with results that reflect the non-institutionalized, civilian U.S. population. The survey is conducted in two parts: individuals first participate in a health interview in their homes, then undergo a physical exam and provide blood samples at a mobile examination center.

Analysis

Only submariners from whom a complete set of data could be obtained were included in the study population. It is assumed that the distribution of submariners who had complete or incomplete data was approximately random since there was no specific category of individuals who regularly received different labs or medical treatment. As mentioned before, available data was used only if it was obtained during the previous five years.

The complete data for both submariners and U.S. civilian males were analyzed using Microsoft Excel. Standard error for proportions was calculated using formulas from Colton[17] and z-tests for proportional differences were computed using Statistica[©] and following formulas from Fleiss et al.[18] Wherever the actual metabolic syndrome criteria are concerned, only the specific values as outlined in Table 1 were used to determine the prevalence of each. Results for both groups were first compiled for overall prevalence, and then stratified according to age and BMI. Finally, the data obtained from submariners was stratified according to rank (i.e. junior enlisted, senior enlisted, and officer).

RESULTS

Overall, the medical records for 1184 sailors from eight submarines were screened. Of these, 734 individuals had complete data. At the time data was collected, the sailors ranged in age from 17 to 44 years. The mean age was 26.5 years with a standard deviation of 5.8 years. BMI ranged from 17.3 kg/m^2 to 39.5 kg/m^2, with a mean of 26.1 kg/m^2 and a standard deviation of 3.7 kg/m^2. There were 474 junior enlisted (E1 – E5), 154 senior enlisted (E6 – E9), and 103 officers (O1 and above) in this study.

The raw NHANES 2005-2006 data contained information on 5080 men. Individuals who either did not have complete data or fasted less than 8 hours prior to providing a blood specimen were eliminated were excluded from analysis, as were those younger than 19 or older than 44. Among the 408 remaining men, the mean age was 30.4 years, with a standard deviation of 8.0 years. BMI ranged from 17.4 to 130.2 kg/m^2, with a mean of 28.2 kg/m^2 and a standard deviation of 8.1 kg/m^2.

The following clinical abnormalities were noted among the Groton submariners. FBG ≥100 mg/dl was documented in 58 of individuals screened. 452 of the individuals were overweight (BMI ≥25) or obese (BMI≥30). Deficient HDL was found in 239 individuals. Elevated TG was documented in 85 individuals. HTN (>130/85) was prevalent in 247 of the crewmembers. Of the comparably-aged 408 U.S. Males in the NHANES 2005-2006 data set, 140 of individuals screened had impaired FBG, 259 were overweight or obese, 92 were found to have low HDL, 113 demonstrated elevated TG, and 103 of the men were hypertensive.

Prevalence estimates of the above clinical abnormalities (percent ± standard error) for the Groton submariners and age-matched U.S. males are summarized and compared in Table 2. The table demonstrates that impaired FBG is over four times more prevalent among

the civilian males (34.3 ± 2.4 percent) than among the submariners (7.9 ± 1.0 percent). While similar proportions of the Groton submariner and U.S. male population are overweight, the prevalence of frank obesity is almost twice as great among civilians (26.7 ± 2.2 percent versus 13.9 ± 1.2 percent). Civilian males similarly have more than a two-fold increase in hypertriglyceridemia observed in this study (27.7 ± 2.2 percent among U.S. males versus 11.5 ± 1.2 percent for the submariners). Conversely, prevalence of low HDL and hypertension are greater among the submariners than civilian males (32.5 ± 1.7 percent and 33.6 ± 1.7 percent versus 22.5 ± 2.1 percent and 25.2 ± 2.2 percent, respectively).

Table 3 stratifies the number of cases of metabolic syndrome discovered among the sailors and U.S. males according to age, BMI and rank in the case of submariners only. Among the submariners, the number of cases detected is greatest for men in the fourth decade of life, with 20 cases detected in sailors between the ages of 30 and 34 according the ATP-III definition and 38 according to the IDF criteria. Despite being three times larger than the 30-34 year-old group, the total number of cases detected among sailors between the ages of 20 and 24 was actually lower, yielding just 12 cases according to the ATP-III definition and 29 cases according to IDF criteria. 40-44 year-old submariners comprised the smallest subgroup studied. Their corresponding contribution to the total number of metabolic syndrome cases detected was similarly small, at just four cases by the ATP-III definition and five cases by the IDF definition.

Among males who participated in NHANES 2005-2006, the age groups between 20 and 44 years were comparable in size to each other, but the number of metabolic syndrome cases detected in each group increased with age. Males under 20 had the fewest cases at just 3 and 5 according to ATP-III and IDF guidelines, respectively. The 35-39 year-olds produced the most cases at 27 and 30 cases, respectively. The 40-44 year old group produced only slightly fewer cases of metabolic syndrome than the 35-39 year-olds. Table 4 compares prevalence estimates of metabolic syndrome for Groton submariners and comparably aged U.S. males who participated in NHANES 2005-2006 stratified according to age, BMI and rank for sailors.

Table 2. Prevalence of clinical conditions that are establishing criteria for metabolic syndrome.

Clinical Abnormality	Total Among Submariners (n=734)	Total Among U.S. Males (n=408)	Prevalence Among Submariners	Prevalence Among U.S. Males
FBG≥100	58	140	7.9 ± 1.0	34.3 ± 2.4
BMI >25	452	259	61.4 ± 1.8	63.5 ± 2.4
BMI >30	102	109	13.9 ± 1.2	26.7 ± 2.2
HDL<40	239	92	32.5 ± 1.7	22.5 ± 2.1
TG>150	85	113	11.5 ± 1.2	27.7 ± 2.2
BP≥130/85	247	103	33.6 ± 1.7	25.2 ± 2.2

Table 3. Stratification of metabolic syndrome cases according to age, BMI, and rank.

	Groton Submariners			NHANES Males		
	N	ATP-III	IDF	N	ATP-III	IDF
Total	734	63	118	408	85	106
Age (years)						
<20	29	0	1	48	3	5
20-24	332	12	29	75	5	9
25-29	174	13	26	70	13	17
30-34	109	20	38	72	12	16
35-39	67	14	19	74	27	30
40-44	23	4	5	69	25	29
BMI (kg/m^2)						
<25.00	280	4	0	149	5	0
25.00-29.99	352	20	79	143	16	42
>30.00	102	39	39	116	64	64
Rank						
E1-E5	477	26	58	-	-	-
E6-E9	154	30	46	-	-	-
O1-O5	103	7	14	-	-	-

Using the ATP-III definition, the overall prevalence of metabolic syndrome for Groton submariners was 8.6 ± 1.0 percent, compared to 20.8 ± 2.0 percent of U.S. males between the ages of 19 and 44. By comparison, the overall prevalence for each of these populations according to the IDF criteria was 16.2 ± 1.4 percent and 26.0 ± 2.2 percent, respectively. Prevalence among the submariners generally increases toward the end of the fourth decade of life, regardless of definition applied. After that, the prevalence decreased slightly. This was not the case with U.S. males, whose prevalence generally increased over time. The association between age and prevalence is supported in Figure 1, which compares the age-stratified prevalence of metabolic syndrome of Groton-based submariners with all U.S. males, as determined by data obtained from the NHANES 2005-2006 study.

Table 4. A comparison of stratified prevalence rates between Groton Submariners and U.S. males.

	Groton Submariners			NHANES Males		
	N	ATP-III	IDF	N	ATP-III	IDF
Overall	734	8.6 ± 1.0	16.2 ± 1.4	408	20.8 ± 2.0	26.0 ± 2.2
Age (years)						
<20	29	0	3.4± 3.3	48	6.3 ± 3.5	10.4± 4.4
20-24	332	3.6 ± 1.0	8.8 ± 1.5	75	6.7 ± 2.9	12.0 ± 3.8
25-29	174	7.5 ± 2.0	14.9 ± 2.7	70	18.6 ± 4.6	24.3 ± 5.1
30-34	109	18.3 ± 3.7	34.9 ± 4.5	72	16.7 ± 4.4	22.2 ± 4.9
35-39	67	20.9 ± 4.9	28.4 ± 5.5	74	36.5 ± 5.6	40.5 ± 5.7
40-44	23	17.4 ± 7.7	21.7 ± 8.4	69	36.2 ± 5.8	42.0 ± 5.9
BMI (kg/m^2)						
<25.00	280	1.4 ± 0.7	0	149	3.44 ± 1.5	0
25.00-29.99	352	5.7 ± 1.2	22.5 ± 2.2	143	11.2 ± 2.6	29.4 ± 3.8
>30.00	102	38.2 ± 4.8	38.2 ± 4.8	116	55.2 ± 4.6	55.2 ± 4.6
Rank						
E1-E5	477	5.5 ± 1.0	12.2 ± 1.5	-	-	-
E6-E9	154	19.5 ± 3.2	29.9 ± 3.7	-	-	-
O1-O5	103	6.8 ± 2.5	13.6 ± 3.4	-	-	-
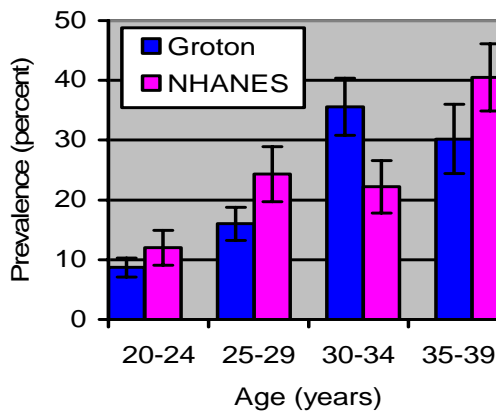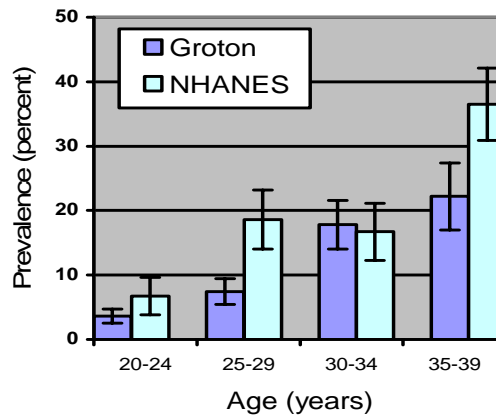
(a)   **(b)**

Figure 1. Prevalence of metabolic syndrome stratified by age (a) according to the ATP-III criteria and (b) according to IDF guidelines.

Figure 1 demonstrates that submariners under age 20 had the lowest estimated prevalence of metabolic syndrome, at just 3.4 ± 3.3 percent based on the IDF criteria. This estimate was substantially lower than for the US male population, which was 6.3 ± 3.5 percent and 10.4 ± 4.4 percent according to ATP-III and IDF guidelines, respectively. The 35-39 year-olds demonstrated the highest prevalence of metabolic syndrome within the submariner population according to ATP-III guidelines, at an estimated 20.9 ± 4.9 percent. While this ATP-III-based estimate is lower than its counterpart in the U.S. male population, it is noteworthy that the estimated prevalence of metabolic syndrome among 30-34 year-old submariners (18.3 ± 3.7 percent) is actually higher than for similarly aged civilians (16.7 ± 4.4 percent) when using IDF criteria. More importantly, according to the IDF criteria, 30-34 year-olds had the highest prevalence among submariners, at 34.9 ± 4.5 percent. Not only is this prevalence estimate higher than the IDF estimate for all U.S. males aged 30-34 (22.2 ± 4.9 percent), but the standard errors for both of these estimates do not overlap. However, this difference was found not to be significant ($z=-1.85$).

The prevalence of metabolic syndrome among 40-44 year-old submariners was estimated as 17.4 ± 7.7 percent according to ATP-III criteria and 21.7 ± 8.4 according to IDF

guidelines. While these estimates were higher for this group than for all groups of submariners under age 30, they constituted the smallest fraction of total cases among all sailors. This finding was not unexpected, since 40-44 year old submariners comprised the smallest age group in this study with just 23 individuals. Further, the large standard error of sampling for both of these estimates suggests that neither is valid. By comparison, prevalence estimates for US males between 40 and 44 years were 36.2 ± 5.8 percent and 42.0 ± 5.9 percent based upon ATP-III and IDF criteria, respectively. This group was over three times larger than its submariner counterpart, but still has a significant sampling error.

Figure 2 compares the prevalence of metabolic syndrome among Groton submariners stratified by BMI with the U.S. male population. While prevalence rates among submariners never approach those of the civilian population, it is clear that there is a direct relationship between BMI and metabolic syndrome. The prevalence reaches a high of 38.2 ± 4.8 percent for Groton submariners with a BMI of 30 kg/m^2 or greater using either criteria. It is noteworthy that this estimate was the same using either the ATP-III or the IDF criteria. This result occurred because any BMI within this range satisfies the necessary criterion for central obesity put forth by the IDF as well as the sufficient condition established by the NCEP when drafting the ATP-III guidelines. Note also that in this study prevalence estimates based upon IDF guidelines are not performed for individuals with BMI less than 25 kg/m^2.
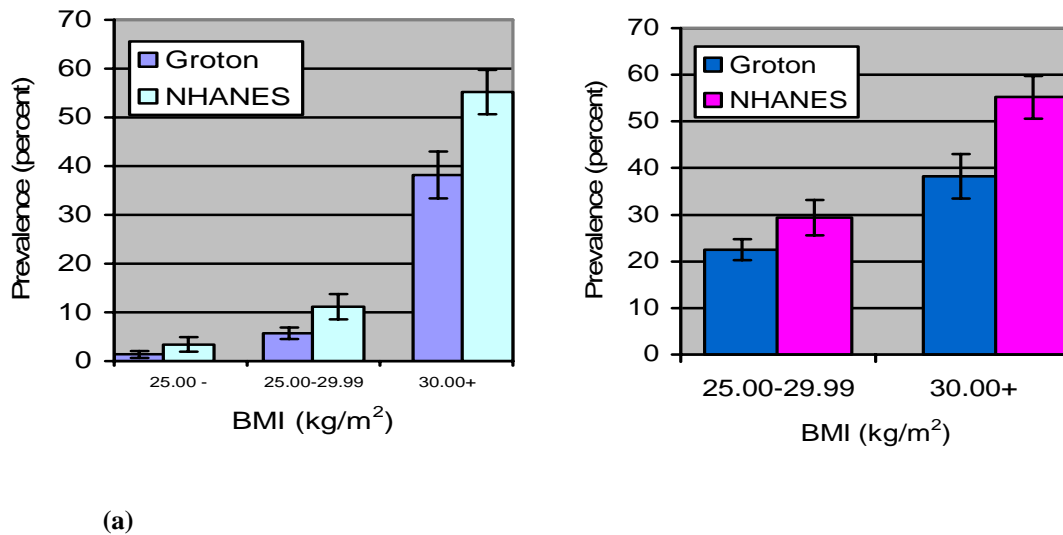

(a)

(b)

Figure 2. Prevalence of metabolic syndrome stratified by body mass index (a) according to the ATP-III criteria and (b) according to IDF guidelines.

Figure 3 provides a comparison of prevalence of metabolic syndrome according to rank. Junior enlisted sailors demonstrated the lowest prevalence. Estimates according to ATP-III and IDF criteria were 5.5 ± 1.0 percent and 12.2 ± 1.5 percent, respectively. Officers (O1-O5) had prevalence rates only slightly higher than those of the junior enlisted personnel at 6.8 ± 2.5 percent and 13.6 ± 3.4 percent. Senior enlisted submariners (E-6 through E-9) had the highest prevalence, with a low estimate of 19.5 ± 3.2 percent

according to the ATP-III criteria and a high estimate of 29.9 ± 3.4 percent according to the IDF definition. It is noteworthy that these prevalence estimates also correspond to those stratified by age, since the average age of the junior-enlisted sailors was 23.5 ± 3.5 years, the average age of the senior-enlisted sailors was 33.9 ± 5.0 years, and the average age of the officers was 28.9 ± 4.7 years.

Of all the clinical abnormalities measured in this study, obesity was most prevalent among submariners with metabolic syndrome. 96.8 percent of the submariners studied who met ATP-III criteria were clinically overweight or obese. Conversely, only 1.4 percent of submariners who were not overweight met the ATP-III criteria for metabolic syndrome. According to IDF guidelines, central obesity is a prerequisite for metabolic syndrome. It was therefore present in all such diagnoses.
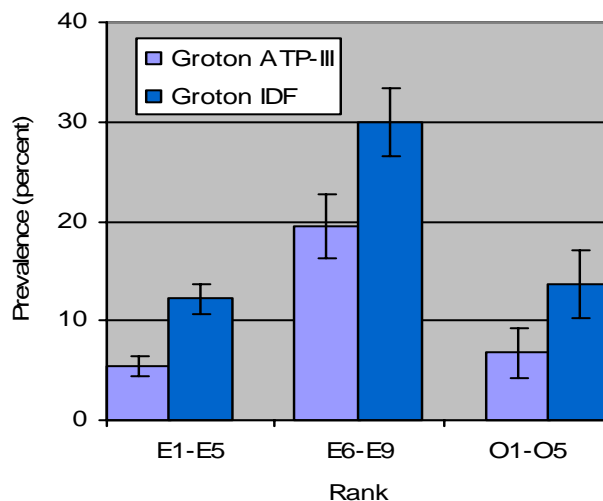

Figure 3. Prevalence of metabolic syndrome stratified according to rank.

After obesity, HDL deficiency appears to have the greatest impact on prevalence of metabolic syndrome within the submariner study group. 81.0 percent of submariners studied satisfying the ATP-III requirements for metabolic syndrome exhibited low serum HDL, as were 79.6 percent of those satisfying the IDF requirements. Using the ATP-III definition, 20.5 percent of the Groton submariners in the study who had low HDL also had metabolic syndrome. 39.3 percent of the submariners with low HDL were diagnosed with metabolic syndrome according to the IDF guidelines. Among submariners studied with normal HDL levels, only 2.6 percent were diagnosed with metabolic syndrome according to ATP-III guidelines, and 5.1 percent according to IDF criteria.

Among the sailors, hypertension was present in 82.5 percent of all ATP-III cases and 71.1 percent of all IDF cases. Of all the hypertensive sailors screened, 35.4 percent had metabolic syndrome according to ATP-III guidelines, as did 20.9 percent according to IDF guidelines. Only 2.7 percent of normotensive individuals met the ATP-III requirements for metabolic syndrome. Similarly, 7.6 percent normotensive sailors were diagnosed with metabolic syndrome according to IDF criteria.

68.2 percent of Groton submariners with metabolic syndrome according to ATP-III guidelines demonstrated elevated fasting triglycerides, versus 52.5 percent according to IDF guidelines. By comparison, 3.1 percent of those evaluated with normal triglycerides met the ATP-III criteria for metabolic syndrome, and 8.8 percent of the same group satisfied the IDF criteria.

Impaired fasting blood glucose contributed less to the prevalence of metabolic syndrome than any of the other clinical prerequisites among the Groton submariner study group. Only 33.3 percent of submariners who met the ATP-III requirements for metabolic syndrome exhibited impaired fasting blood glucose. At 25.4 percent, prevalence of impaired fasting blood sugar was slightly lower in members who were categorized as having metabolic syndrome according to the IDF guidelines. 47.6 percent of those diagnosed under ATP-III guidelines and 48.3 percent of individuals diagnosed under IDF guidelines had at least three other clinical abnormalities besides elevated FBG. Among submariners with normal fasting blood glucose, 6.1 percent and 12.7 percent were diagnosed with metabolic syndrome according to ATP-III and IDF guidelines, respectively. These percentages of prevalence in the absence of a particular clinical abnormality were greater than for any other prerequisite condition.

DISCUSSION

A significant drawback to the methods utilized in this study was the use of BMI data in lieu of waist circumference measurements. In doing so, it is likely that prevalence according to the IDF definition was underreported for individuals with BMI less than 25.00 kg/m^2. However, the comparisons made between the submariners and males surveyed in NHANES 2005-2006 are still valid because BMI was substituted for waist circumference when studying each group. Further, analysis of anthropometric data obtained from NHANES 2001-2002 demonstrated that utilizing a BMI of 28.2 kg/m^2 yielded close agreement between prevalence estimates utilizing BMI and waist circumference data.[19] A similar finding was made from the NHANES 1999-2000 data.[18] Thus, if the cutoff for obesity in this study were lowered to 28.2 kg/m^2, prevalence among submariners according to ATP-III criteria increases to 10.1 ± 1.1 percent. Similarly, the prevalence estimate for the NHANES 2005-2006 males increases to 23.6 ± 2.1 percent. Therefore, it is likely that our prevalence estimates are conservative.

Another disadvantage to this study was the lack of synchronization of the data collected from the submariners. At the time of collection, the height and weight data obtained from each service member's PFA was no more than 6 months old. In contrast, blood pressure and serologic data obtained from each member's PHA was up to five years old, as was similar data culled from Submarine Duty physical examinations. However, it has been demonstrated that individuals with normal to high-normal blood pressure often progress to frank hypertension over a period less than five years.[20,21] Borderline dyslipidemia and fasting glucose similarly tend to worsen over time.[22,23] Therefore, it is again probable that this study actually underreports the prevalence of metabolic syndrome among the Groton submariner group.

While the rates of obesity detected in both study groups were similar, males in the NHANES group were generally more obese, with a mean BMI over 2 kg/m^2 greater than that of the Groton submariner group. This disparity between the two groups was expected. Each branch of the U.S. military has height and weight standards for enlistment, commissioning, and advancement. These standards usually prevent morbidly obese individuals from entering or remaining in the military.

It is important to note that the data obtained through NHANES 2005-2006 is intended to represent the non-institutionalized, civilian U.S. population.[16,19] Consequently, age-matching was difficult for this study, as in the military the overwhelming majority of the population is younger, with older individuals comprising the senior officer and enlisted leadership. Thus, there were only 23 sailors in the 40-44 year-old group, but almost fifteen times as many in the 20-24 year-old group. By contrast, the NHANES population had 69 and 75 men distributed throughout these respective age groups. Despite excluding data from males who fell outside of the age range of the Groton Submariners studied, the mean age of the NHANES males was more than five years greater. When stratifying cases by age, standard error reached as high as 8.4 percent in the 40-44 year-old submariners. This large standard error suggests that a greater test population of older subjects is needed before any valid conclusions could be drawn regarding prevalence of metabolic syndrome within this group.

There are several studies demonstrating direct relationship between age and BMI within the U.S. civilian population.[24-26] Similarly, both age and BMI were shown to be directly associated with metabolic syndrome prevalence within this same population.[1,2,4,19,27] Therefore, prevalence estimates among submariners and civilian males may have been closer if the age matching were closer.

Glucose intolerance had less of an effect on prevalence among the Groton submariners than any other clinical abnormality. In fact, the prevalence of elevated FBG among the submariners was barely one-fifth of what was observed in the NHANES group. This finding is likely because diabetes mellitus is disqualifying for both enlistment in the Navy and submarine duty.[15] Additionally, submariners diagnosed with impaired glucose tolerance require a medical waiver in order to remain on submarine duty.[28] Despite the fact that elevated FBG appeared to have the least effect on prevalence of metabolic syndrome among the submariners, absence of this data was an important limiting factor in determining sample size. Of the 450 sailors who were not included in the study due to incomplete screening data, 404 were missing FBG. Out of these sailors excluded, exactly half were missing only FBG.

CONCLUSION

The overall prevalence among fast-attack submariners is significantly lower than for civilian males. Like civilian males, prevalence of metabolic syndrome among the submariners increases with age, up until age 40. Beyond that, data are insufficient to assess for trends. The prevalence of metabolic syndrome for submariners is also directly

correlated to BMI, as is the case with civilian males. Senior-enlisted sailors have the highest prevalence of metabolic syndrome among submariners. Regardless, it is premature to state that there is an epidemic of metabolic syndrome among fast-attack submariners, based on the data at hand. In the future, a more precise prevalence estimate could be made for this population if FBG were required as a part of the submarine duty physical examination or PHA.

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